Higher 2 (9173)	Cluster 2: Tropical Environments	TMJC
Lecture 11	*Channel Patterns and Deltas*	2025

LECTURE OBJECTIVES

1. Explain the meandering and braided channel patterns
2. Compare the characteristics and conditions that leads to the formation of meandering and braided channels
3. Explain how the characteristics of the drainage basin affect the drainage efficiency

Introduction

Channel Patterns:

Channel	Straight	Meander / Sinuous	Braided Channel
Photo			
Plan View			
Cross-section view			

(A) WHAT IS A MEANDER CHANNEL PATTERN?

1. A meandering channel is a sinuous channel with a sinuosity index of at least 1.5 with asymmetrical cross-sections, formed by erosion on the outer bank and deposition on the inner bank.

2. In terms of channel features present, meandering channels contain pool and riffle sequences as well as river cliffs and slip-off slopes (Fig. 1).

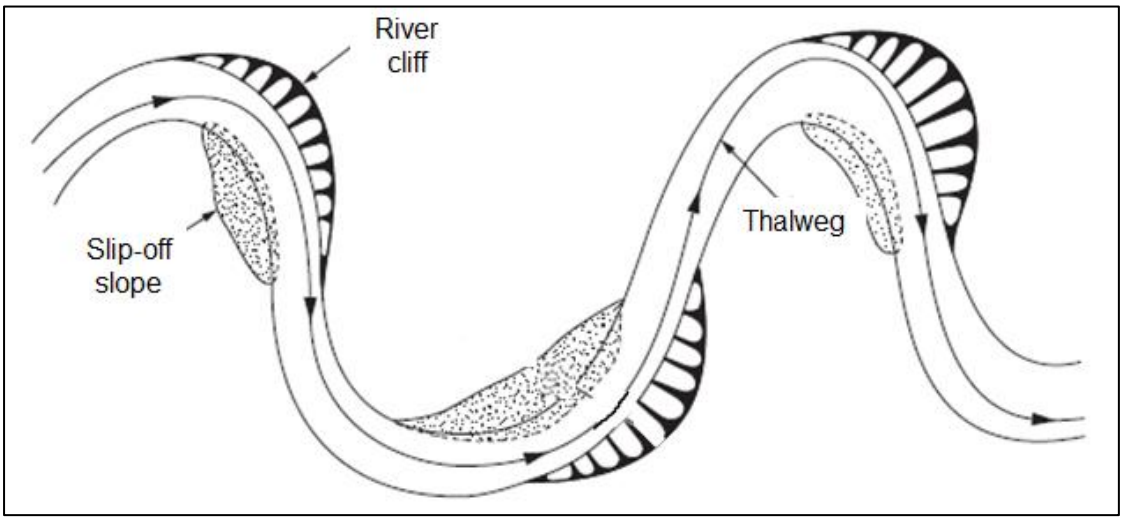


Fig. 1: Meander Channel Pattern

Sinuosity is a measure of how irregular a stream's path is.

Sinuosity is measured by the Sinuosity Index, which is obtained by dividing channel length between 2 points by the straight line distance between the two points (also known as the downvalley length).

Sinuosity index = Channel length between A and B/Downvalley length

Where sinuosity is 1.0, it shows that channel length is equal to the straight line distance, meaning it is a straight channel.

(B) HOW IS A MEANDER CHANNEL PATTERN FORMED?

1. The main condition required for the formation of meander channel patterns is the presence of an **alternating pool and riffle sequence**.

    a. Any form of turbulence will create decelerated flow of water resulting in deposition forming a riffle. This deposition result in release of energy allowing for accelerated flow which causes erosion, creating a pool.

    b. Alternating pool and riffle sequences refer to alternating occurrences of pools (areas of deep water) and riffles (areas of shallow water) along the river channel[1]. Typically the distance between the pools are 5–7 times the bed width of the river.

    c. Pool and riffle sequences may affect channel form by increasing the sinuosity of the channel which will then eventually lead to the formation of meanders once the sinuosity index exceeds 1.5.

2. Thus, meanders form as a result of differences in channel efficiency and competence over space due to the pool and riffle sequence.

3. Along a straight section of a river, a pool and riffle sequence results in a diversion of the thalweg (the path of maximum velocity) from side to side of the river banks due to diffusion over riffles.

    a. This causes the thalweg to develop a sinuous course.

    b. As the thalweg swings, it results in erosion on the outer bank due to higher velocities of flow and deposition on the inner bank to form point bars due to reduced flow velocities and reduced channel competence (Fig. 2).

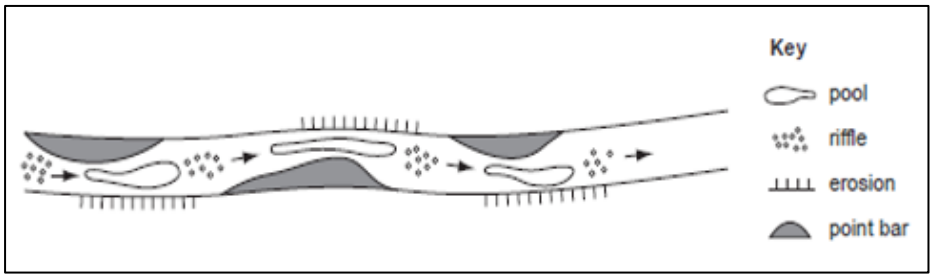


Fig. 2: Diversion of thalweg due to pool-riffle sequence

4. When the river emerges from the bend, it encounters the riffles in the channel and due to the shallowness of the riffles, velocity falls and deposition of material takes place.

5. The river, having deposited sediment on the riffles, emerges with more energy.

6. As the thalweg swings to the next bend, this results in increased erosion of the outer bend again. This makes the channel more sinuous and also creates an asymmetrical channel at the meander bend (Fig. 3).

[1] Riffles are formed in shallow areas by coarser materials such as gravel deposits over which water flows. Pools are deeper and calmer areas whose bed load (in general) is made up of finer material such as silt.

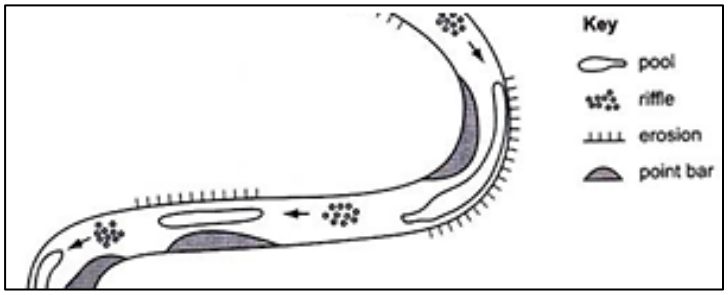


Fig. 3: Increasing sinuosity of the channel, with pools at the apex of the curvature and riffles at inflexion points

7. The swinging thalweg in a meander system also generates a secondary flow known as helicoidal flow, which is a corkscrew-like flow of water (Fig. 4).

    a. The high velocity flows hit the banks of the channel with force before dropping with gravity.

    b. There is a surface movement of water to the outside of a meander bend, and a return drift at the bed.

    c. This results in erosion and undercutting of the channel bank, accompanied by deposition on the convex bank opposite.

8. This accentuates the asymmetrical nature of the channel as erosion occurs on the outer bank to form river cliffs, while deposition occurs on the inner bank to form slip-off slopes.

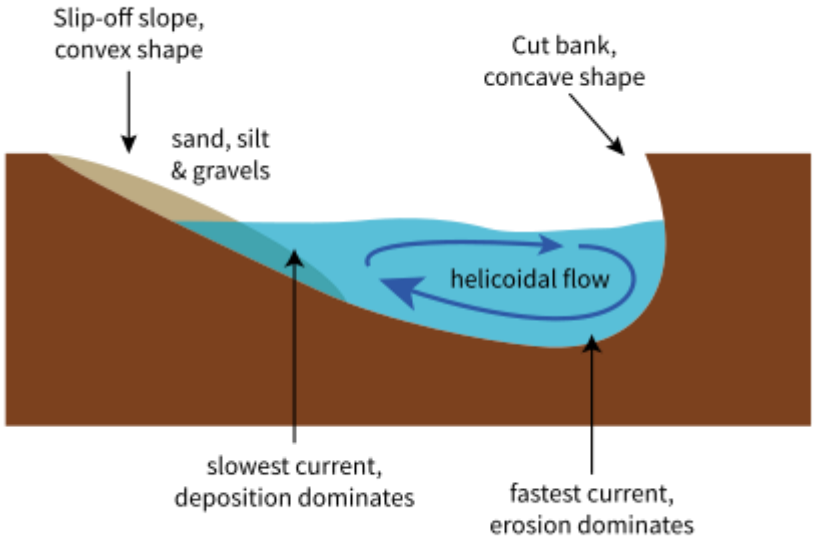


Fig. 4: Helicoidal Flow

9. In fully developed meanders, pools are located at the apex of curvature close to the cut bank where flow velocity is highest.

10. These pools are areas of scour, laminar flow, deep water and fine sediment. Riffles occur on crossover points of channel where the thalweg swings from one bank to the other. They are areas of shallow water, coarse sediments, steep gradient and turbulent flow.

11. Meandering rivers can migrate laterally due to erosion on the outer banks of the channel and transference of materials to the inner banks, increasing the sinuosity of the meander. When 2 meander bends intersect, they may form horse-shoe shaped lakes known as oxbow lakes.

12. The availability of higher continuous input of water is essential in the formation of meandering channels and hence meandering channels are found largely in the humid tropics. An example of a meandering channel in the humid tropics is the Mamore River in Bolivia and Brazil within the Amazon Basin.

(C) WHAT IS A BRAIDED CHANNEL PATTERN?

1. A braided channel is a channel in which there is not one single channel but a series of small interconnecting channels separated by **mid-channel bars (eyots)** (Fig. 5).

2. The whole body of bars are located within the banks of the channel and which is referred to as a **containing channel.**

3. The individual channels within the containing channel is known as **anabranches/ anastomising streams.**

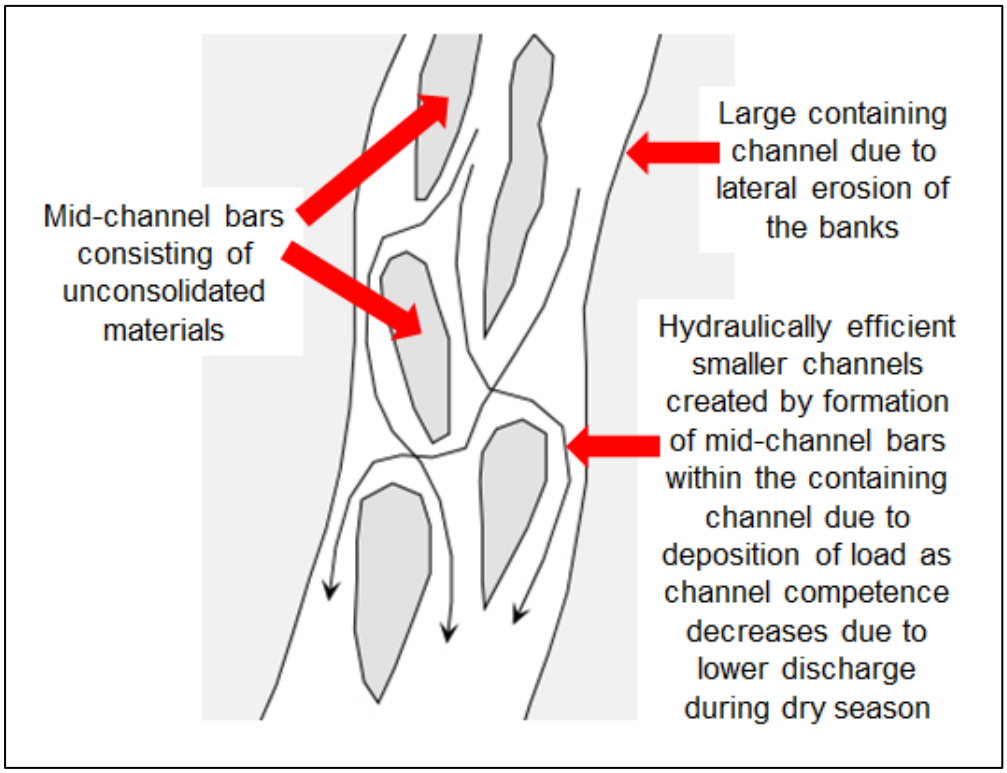


Fig. 5: Features of a braided channel pattern

(D) HOW IS A BRAIDED CHANNEL PATTERN FORMED?

1. There are three main conditions leading to the formation of braided channel patterns.

2. Braided channel patterns tend to form in streams having (1) highly variable discharge, (2) high sediment load and calibre, as well as (3) easily erodible banks that form broad containing channels and supply abundant sediment load to the stream.

3. Braided channels therefore form as a result of the variation of channel hydraulic efficiency and channel competence over time.

4. During periods of high discharge, a stream with easily erodible banks may carve out broad channels, where the high discharge increases channel competence and provides energy for bank and bed erosion to take place. These broad channels are thus hydraulically efficient (possess high hydraulic radius) during periods of high discharge (Fig. 6).

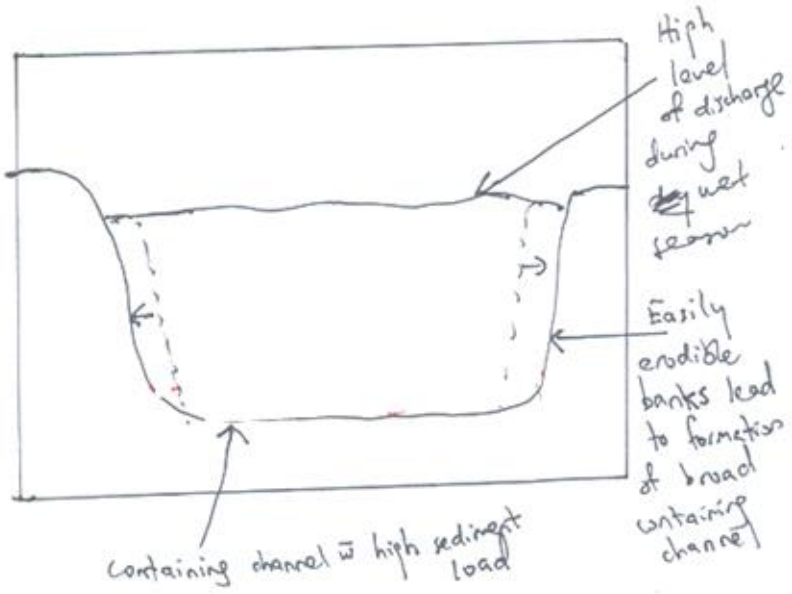


Fig. 6: Broad containing channel carved out during a period with high discharge to produce a hydraulically efficient channel

5. However, during periods of low discharge (such as during the dry season), the broad bed of the containing channel makes it hydraulically less efficient (lower hydraulic radius) due to the relatively greater wetted perimeter compared to the cross-sectional area. The increased friction results in lower velocities and hence river energy.

6. The reduced velocity will (as represented by Hjulstrom's Curve) result in reduced competence and capacity of the stream, causing the coarsest sediment to be deposited in low energy (velocity) areas along the channel bed. These sediments form the basis for further deposition to form temporary mid-channel bars (also known as eyots) that locally divides the flow and concentrates it in narrower but deeper segments of the channel on either side (Fig. 7).

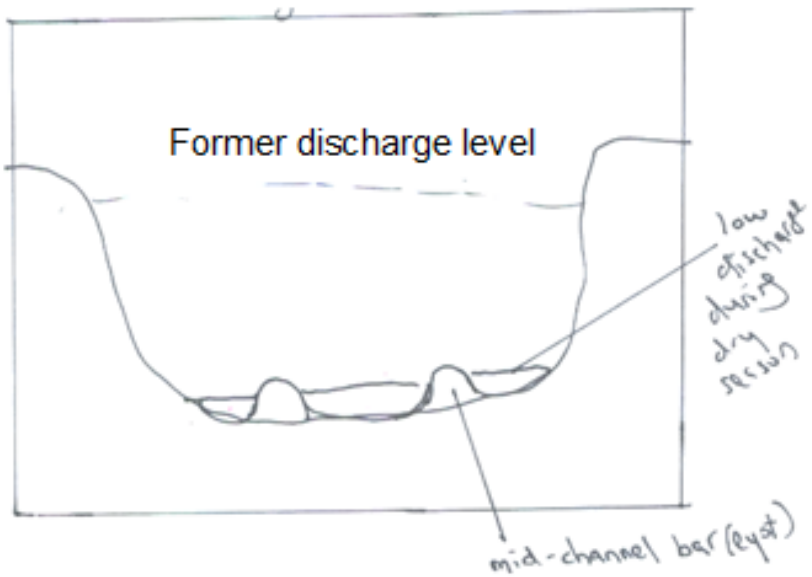


Fig. 7: Formation of mid-channel bars during periods of low discharge resulting in hydraulically efficient smaller channels within the containing channel

7. Each branch of flowing water around an eyot is more competent than the original channel as the decrease in width results in a decrease of wetted perimeter and subsequent increase in the hydraulic radius. As such braided channels are hydraulically more efficient than the containing channel itself for low discharge levels. As the bar builds up, it may emerge above the surface as an island and become stabilized by vegetation that anchors the sediment and inhibits erosion.

8. Thus, due to the changing morphology of the river channel over time in terms of its cross sectional area, wetted perimeter and hydraulic radius, the dominant process in the river channel changes from erosion of the banks to the deposition of suspended material to form mid-channel bars, resulting in the creation of a braided channel pattern.

9. Meltwater streams issuing from glaciers generally have a braided pattern because the discharge varies both daily and seasonally, and the glacier supplies the stream with large quantities of sediment. An example of braided streams include the Brahmaputra-Jamuna River in the state of Assam in Bangladesh. It is fed by sediments and discharge from the Himalayan region upstream.

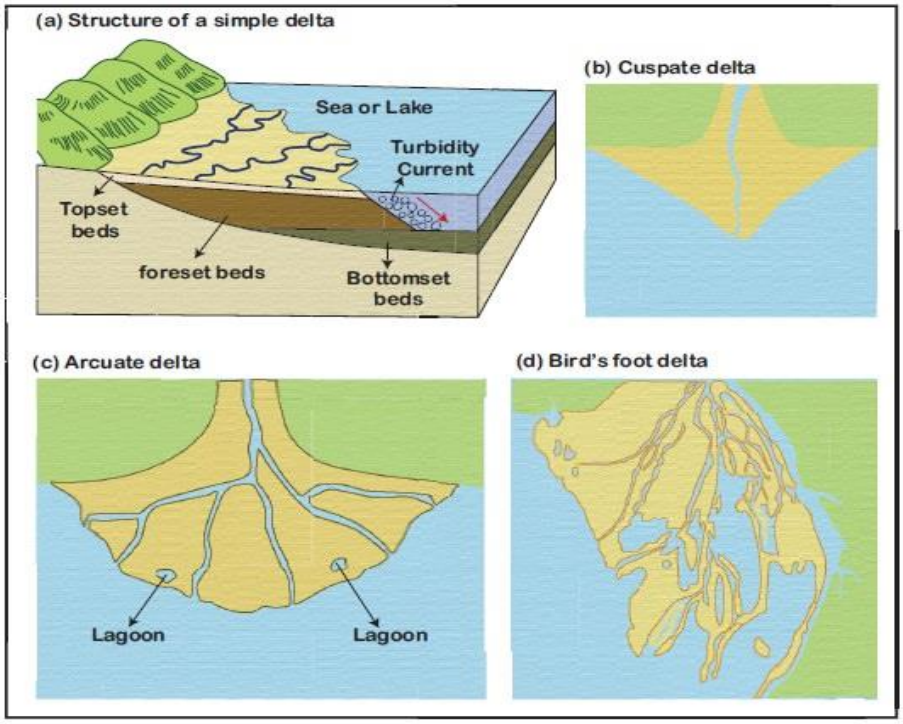
(E) DELTAS

Deltas

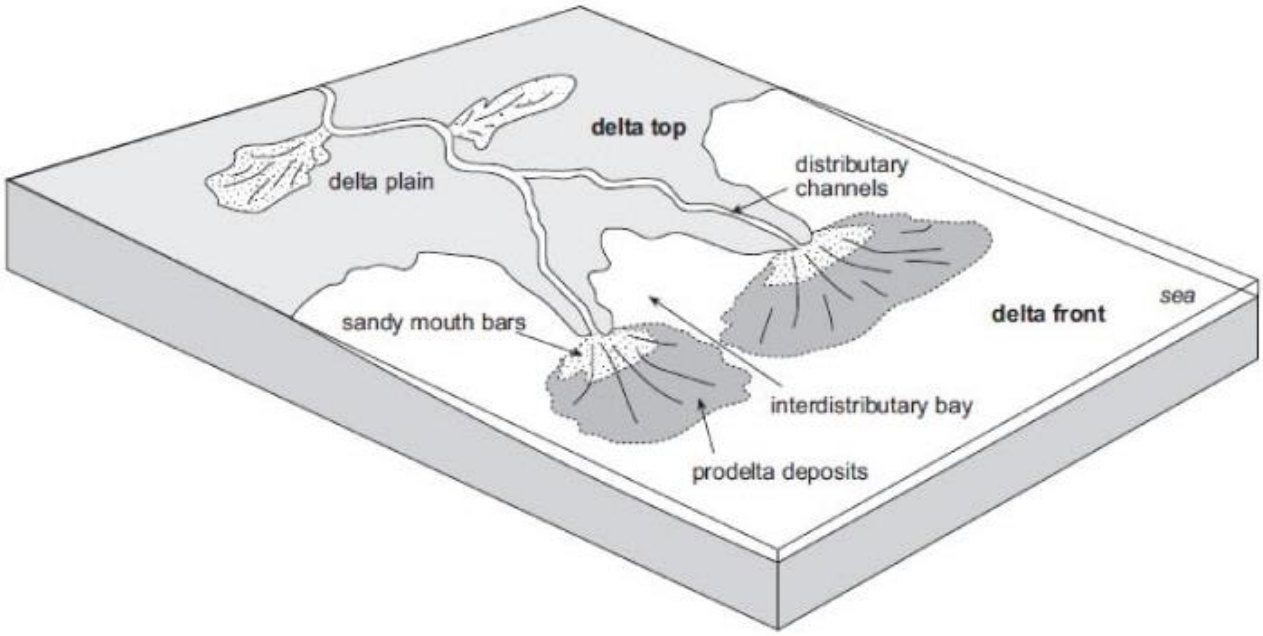
Deltas are fan-shaped deposits formed from built-up layers of sediments deposited by a river where it enters a standing body of water like a lake or calm sea. The river may have to branch into smaller distributaries to carry the water to the sea.

Types of deltas

- Arcuate delta → triangular in shape e.g. Nile Delta
- Bird's foot delta → e.g. Mississippi Delta



Features of a delta



A delta is divided into three major morphological subdivisions,

1. Delta plain: Highly extensive, lowland with active and abandoned distributary channels and levees. The distributary channels are separated from each other with shallow water environment. Variably active series of distributary channels characterize an active delta, but a single distributary channel delta is not uncommon though. These channels are characterized by unidirectional flow, periodic stage variations, and high to low sinuosity depending on grain size and gradient. Although the distributary channels have some similarities with fluvial channels but the lower reach and width to depth ratio of a distributary channel is different from its fluvial counterpart. The lower reach of a distributary channels are affected more by basinal processes, moreover saltwater wedges may penetrate during low water stage. Width to depth ratio of a fluvial channel is much higher than distributary channel due to its limited life span and restricted scope for lateral migration. Interdistributary areas are comprised of swamps, marshes, and enclosed stagnant water bodies that are occasionally disturbed by locally-generated wind wave.
2. Delta front: Influence of basinal processes on sediment-laden fluvial currents are the characteristic of this interaction zone. The flow velocity decreases and sediment deposition initiated due to both lateral and vertical flow expansion as the flow enters the standing body of water. In a fluvial dominated delta the channel deposits coarse-grained distributary mouth bar and disperse finer grain deposits towards offshore as subaqueous levees. Swash bars, beach ridges, beach spits, and cheniers developed either along distributary mouth bars or along the shore towards coastal current drift where wave processes are dominated. A tide-dominated delta is represented by tidal channels along with tidal sand bars as well as ebb and flood tidal deltas.
3. Prodelta: The part of delta that is unaffected by wave or tidal. This is the most stable part of the most common delta types where mud and silt deposited from suspensions as lamination reflecting deposition of fluvial sediments in the buoyant plume. Laminations are preserved in anoxic conditions but disturbed by intense bioturbation in aerobic conditions. Prodelta is uncommon in some shallow water, storm or tide-dominated delta.

Factors affecting the formation of Deltas, particularly factors that favor its formation.

- A large load of sediment

Sediment load determines the rate of delta formation, a river carrying a large sediment load will have more to deposit when it reaches the mouth of the river. Too little sediment load makes it difficult for the delta to accumulate and form.

- Shallow sea at the river mouth

Shallow sea allows for sediments to sink to the bottom and slowly pile up, if the sea is too deep, it will take a much longer time for the sediments to accumulate and pile up to form.

- Sheltered coast with weak tides and currents

Strong tides and currents will have the ability to wash away (we should use the words: **erode and transport)** the sediments into the ocean when the tide comes in and move out along with the tides. This would hinder and delay delta formation.

- Absence of large lakes along the course of the river which will siphon off the load.

Along the course of a river, there could be large lakes which cause the rivers to divert and to transport these carried sediment/load into these lakes instead. One notable example would be the Ton le Sap along the Mekong river.

- Strength of Tidal Waves

Strength of Tidal Waves determines how much load is eroded when the tides ebbs and flows.

Deltas are part of the river channel, though they meet the sea/ lake. Velocity is very much decreased when it reaches a delta. Near the sea, the process of flocculation happens, and binds silty particles into larger ones so that deposition is accelerated, which leads to the formation of deltas over time.

ECOSYSTEM SERVICES PROVIDED BY DELTAS

Deltas are important fluvial landform that support civilisation. They provide fertile soil for agriculture and livelihood. For instance the Mekong river delta is of major economic importance to Vietnam. In 2017, Mekong Delta's gross regional development product (GRDP) growth stood at 7.6 percent, higher than the national average of 6.81 percent. The region's per capita gross domestic product reached US$2,700 per year, with Can Tho, the region's economic hub, having the highest at US$3,500. There are over 53,000 businesses in the region, ranging from agriculture and seafood processing, urban development, transportation, trade, services, and tourism.